Bird Detection in an ATC RADAR scenario

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Abstract— **The detection of flock of migratory birds for ATC (Air Traffic Controller) applications is a crucial issue for the safety of the aircrafts. The long-range and reliable detection of birds can be better achieved by weather RADARs as the RADARs detecting aircrafts are generally sensitive only to targets having bigger RCS (Radar Cross Section) than bird flocks. The distinction between birds and other weather objects (such as clouds, rainfall, snowing, various kinds of clutter etc) can be done by comparing their reflectivity levels, movement pattern, wingbeat frequency levels, velocity, continuity in their structures, vertical levels at different heights etc. The representation of the RADAR data in internationally recognized format is helpful in communicating the data. This paper focusses on the attempts at building relevant software (i.e. algorithm and code) for detecting birds for ATC applications. The birds and cloud (or weather) patches in RADAR has been simulated in this paper and possible extension of the logics involved to the real-time RADAR data is being contemplated. The proposed algorithm distinguishes between birds and cloud patches using diverse features such as their reflectivity levels, movement patterns, velocities etc.**

Keywords— ATC, RADAR, Bird

I. INTRODUCTION

The detection of flock of birds in an ATC scenario may be possible using a marine RADAR with some modifications in the antenna [1]. MMW (Millimeter Wave) RADARs can also be designed for the same purpose [2]. But, in RADARs used for aircraft detection which work only for targets with RCS much larger than that of a flock of bird, bird flock detection cannot be achieved if the RADAR hardware or signal [3] is not available for modifications. In the case of ATC RADARs however, some of the RADARs may have a separate system for weather object detection [4]. The RCS of the weather objects is lower than that of the aircrafts [5]. As the operational weather RADARs can be used for bird detection [6], the data available from the ATC RADAR about weather objects may also be used for bird detection [7]. The weather data available from ATC RADARs is represented in the internationally recognized ASTERIX CAT-008 format. Hence an algorithm has to be developed which will be able to detect bird flock locations from the weather data available from ATC RADARs in ASTERIX CAT-008 format.

II. REFLECTIVITY OF WEATHER OBJECTS

A. Definition

The main factor determining birds in a radar is reflectivity (Z) which is the ratio of total reflected power from the bird divided by the total incident power on the bird. Weather radars in C and S bands have different ranges for the useful levels of reflectivities. The reflectivity threshold is configurable and application based. This threshold may be used to distinguish weather objects. For C band the range of reflectivity for birds is -30 to 10 dBZ [6]. For S band this range becomes -30 to 50 dBZ [6].

B. Dependence of reflectivity on various parameters

Reflectivity (Z) of any aerial object depends on the water content of the air. There are many empirical formulae showing such dependence. However, the dependence of reflectivity on the density of birds flying is given by [6]

$$\eta_{bird}=\text{Mean}(\rho_{bird}.\sigma_{bird}) \qquad (1)$$

where, η_{bird} is bird reflectivity, ρ_{bird} is bird density, σ_{bird} is net average bird RCS, "Mean" is the function to calculate mean and "." is the product operator. The mean is taken over different species of birds [6]. The weather radar data may contain bird flock data as well as the bird body is largely composed of water [8] and the reflectivity level associated with the flock of birds is in the same range of the reflectivity levels of weather objects (cloud, rain, snowing etc.) [9]. Therefore, from the discussion so far it can be said that for C band the range of reflectivity for weather objects is -30 to 10 dBZ [6]. For S band this range becomes -30 to 50 dBZ [6].

In the long range, all the objects detected by weather radar or the weather channel of an ATC RADAR look alike but they can be distinguished by some features of the targets of interest. If the targets of interest are flocks of birds, then the features may be the movement patterns and velocities of the flocks of birds. The movement of the flock of birds will be much more random than that of the clouds [10-14] (or other weather objects) and their velocity is also likely to be higher in magnitude than that of the clouds. The representation of the data coming from the weather channel of the ATC RADAR is done in the ASTERIX CAT-008 format. The algorithm or the logical steps to detect possible bird flock locations must be applied to the weather channel data in order to discard the locations of weather objects and highlighting the possible locations of flock of birds.

III. ALGORITHM & RESULTS

The algorithm developed in the case of simulated data is shown in Fig. 1 as a flow chart. In the flow chart the simulation data has been generated in a way that the weather objects visible in the radar PPI (Plan Position Indicator) display will be of two types: cloud and bird flocks. The weather objects will be visible as pentagons or patches of different shapes and sizes. The choice of pentagons as the geometric representation is random and any other geometric representation may be chosen without loss of generality.

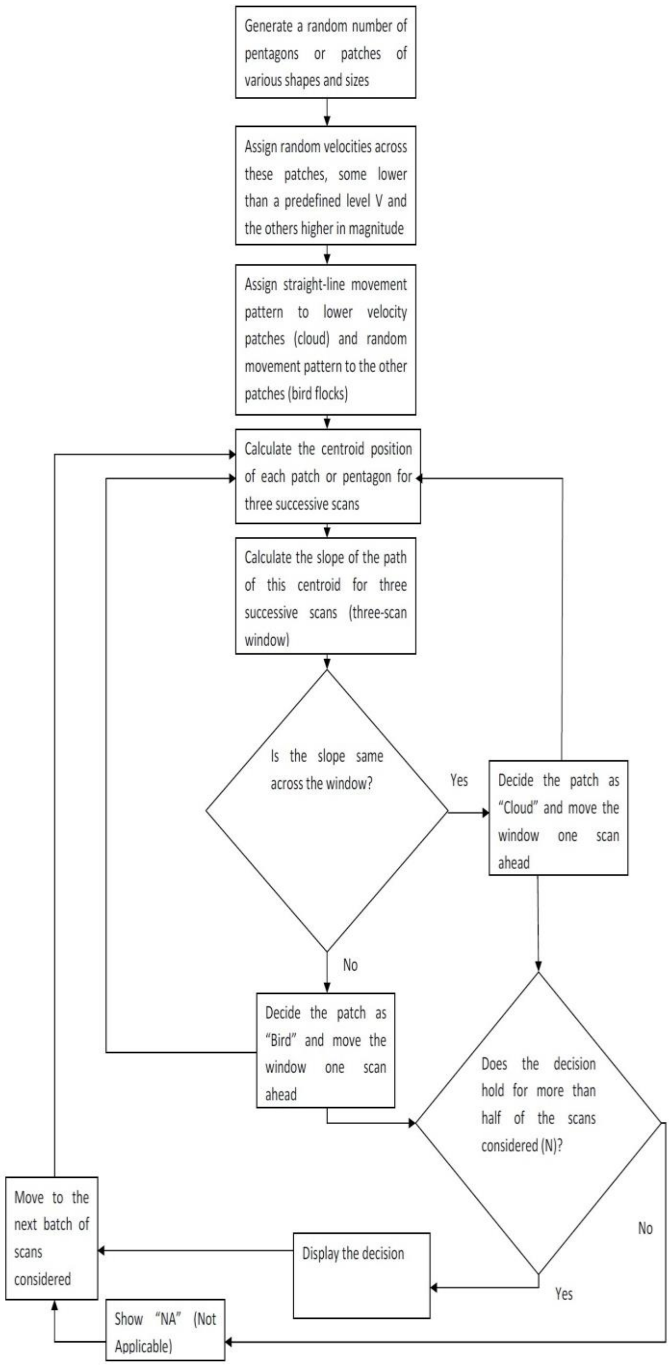

Fig. 1. Bird Detection algorithm used

Let us assume the total number of radar scans for the simulation is N (>=3 since minimum three scans are required for the algorithm as will be explained later) and the velocity level which distinguishes between the velocities of cloud patches and those of bird patches is V. The cloud patches will move in a linear fashion and they will have velocities lower in magnitude than V. The velocity of each cloud patch will be constant but will be chosen randomly from a set of values. The bird patches will move in a random fashion and they will have random velocities higher in magnitude than V. The algorithm must take decisions on the classification of the patches into cloud and bird patches over the N radar scans. This decision has to be taken dynamically over a three-scan window which will keep moving across the N radar scans. After the N radar scans are over, the moving three-scan window will move on to the next batch of radar scans in the next round of the simulation. The reason to have a moving window of three scans length is that atleast three scans are required to calculate the slope of any moving point and the slope calculated helps in identifying the movement pattern of the point. In the simulation, the moving point will be the centroid of each of the pentagons. The moving window will be helpful in calculating the slopes associated with the moving centroids. If a centroid follows the same slope across the three scans, then it is definitely following a straight-line path. On the other hand, if the slopes associated with a centroid keep varying, the centroid is following a random path which is not a straight-line. In the simulation, the basic assumption is that the clouds tend to move more or less in a straight-line path while bird flocks move in a much more random manner [10-14] and decision is taken according to this assumption at the end of each three-scan window for each patch. But, this assumption may not be true for all radar scans. Hence, the decision is based on a majority voting system i.e. if the decisions associated to a patch are same for more than half (or majority) of the scans considered (>N/2), then the decision is displayed at the end of those scans. The bird patches are labelled "Bird" and the cloud patches are labelled "Cloud". The patches for which no definitive decision can be taken at the end of the scans considered, are labelled "NA" which stands for "Not Applicable".

The simulated radar PPI display of weather objects flying has been generated in the simulation for bird detection. This simulation generates moving objects in the PPI display but all the objects ("patches" in Fig. 2) are coloured blue and marked "NA" (stands for "Not Applicable") as the identity of each patch (cloud or bird) is still unknown. The "patches" in the display are pentagons of random sizes and shapes. The circle around each patch has the centroid of the corresponding patch as its centre. The movement of the circle therefore, signifies the movement of the centroid of the corresponding patch. These circles have been generated on purpose because when two patches collide with each other, the circles give an idea of the extent of their closeness. In Fig. 3 however, the velocity and the movement pattern of each patch is being analyzed after a few scans.

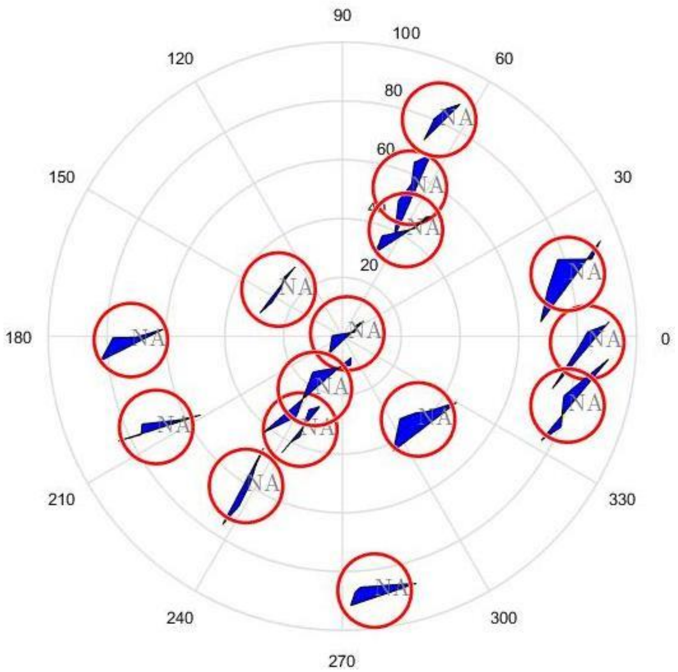

Fig. 2. PPI Display before bird-cloud classification

The assumption is that the bird flocks will be moving at a higher velocity than the cloud patches and the cloud patches will be generally moving in a straight line for most of the radar scans while the movement of the bird patches will be random [10-14]. In order to analyze this movement pattern or the slope of the movement path of the patches, we need to wait for atleast three initial scans as data sufficient for slope calculation is received only after three scans. From the fourth scan onwards, this "three-scan window" keeps moving progressively through the radar scans and the classification of the patches in bird patches and cloud patches keeps getting updated as shown in Fig. 3. The slope each patch follows through the majority of the radar scans considered determines its classification. If the slope remains the same and the velocity of the patch is lower in magnitude than V, then the patch is labelled as “Cloud”. If the slope keeps changing and the velocity of the patch is higher in magnitude than V, then the patch is labelled as “Bird”. The bird patches are given red colour and the cloud patches are given green colour and they are shown in the display after the “three-scan window” has passed through the radar scans considered and has reached the next set of radar scans. The same procedure will happen for the next set of radar scans and the classification of the patches in the radar display will get updated at the end of that set and this process will keep repeating itself. The velocitiy threshold V, number of radar scans N and other parameters (velocities of bird and cloud patches, number of patches which are neither bird nor cloud, the shapes and sizes of the patches and radar scan rate) in the simulation are configurable. The simulated data consists of only bird and cloud patches and no “NA” patches. Hence, the algorithm will show no “NA” patches at the end.

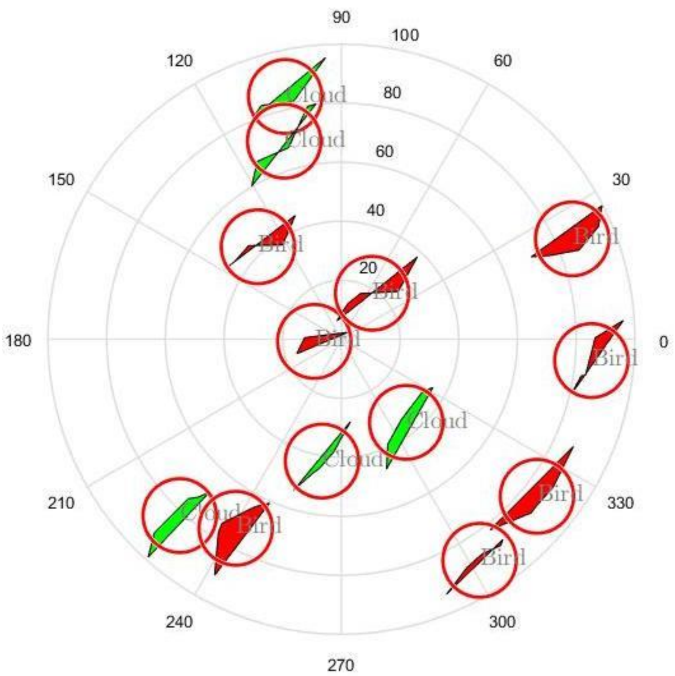

Fig. 3. PPI Display after bird-cloud classification

Applying this kind of algorithm based on the calculation of the slopes of the centroids of moving patches to the real ASTERIX CAT-008 data coming from the weather channel of the ATC RADAR may not be easy or desirable as the data itself is quite different in nature.

IV. DISCUSSION ON ASTERIX CAT-008

ASTERIX CAT-008 is the format in which weather reports are transmitted and received. It consists of two types of messages [15]:

- Weather Message: It describes the weather data field, map, contours of precipitation zones etc.
- Control Message: These are of two types: SOP (Start Of Picture) and EOP (End Of Picture).

These messages remain in every data packet of CAT- 008. In CAT-008, each weather object or “vector” is represented as having an initial point and a line originating from it. The reflectivity of this vector is represented by its colour as different values of reflectivity can be assigned different colours by the user or operator of the radar. The vector may be represented in Cartesian, polar or contour forms. Hence, the “patch” representation described in the simulation discussed in this paper is not applicable to CAT-008.

V. CONCLUSION AND FUTURE WORK

The algorithm discussed in this paper is based on assumptions about the velocities and movement patterns of the weather objects [10-14]. The velocity of the flock of birds is assumed to be higher in magnitude than that of the clouds. The clouds are those patches which move in a straight-line for atleast the majority (more than half) of the radar scans considered while the bird flocks are those patches which move in a random fashion for atleast the majority (more than half) of the radar scans considered. The representation of the weather objects as “patches” in the PPI display is also assumed to create a simplified visual representation. As the data generated in the simulation and the data used in the real-time ATC RADARs may be different in nature, the steps used in the proposed algorithm may not be appropriate for real-time data. In the case of real-time data, new algorithms must be developed by following the approaches related to the proposed algorithm. The new algorithms for the real-time data will require consideration of the nature of the weather data, the range resolution and scan rate of the radar, the known velocities of weather objects and bird flocks and their associated radar returns' lengths etc.

VI. ACKNOWLEDGMENT

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